CLAIMS

[1] A film formation method for forming a metal nitride film having a predetermined thickness on a target substrate by heating the target substrate at a film formation temperature within a process container and performing a cycle comprising a first step and a second step at least once, such that the first step is arranged to supply a metal compound gas and a nitrogen-containing reducing gas to form a film of a metal nitride by CVD, and the second step is arranged to stop the metal compound gas and supply the nitrogen-containing reducing gas,

wherein, in film formation, the target substrate is set at a temperature of less than 450℃, the process container is set to have therein a total pressure of more than 100 Pa, and the nitrogen-containing reducing gas is set to have a partial pressure of 30 Pa or less within the process container in the first step.

[2] The film formation method according to claim 1, wherein a film thickness obtained by the cycle performed once is set to be 0.50 nm or less.

[3] The film formation method according to claim 1, wherein, in the first step, the nitrogen-containing reducing gas is set to have a partial pressure of 20 Pa or less within the process container.

[4] The film formation method according to claim 3, wherein a film thickness obtained by the cycle

performed once is set to be 2.0 nm or less.

[5] The film formation method according to claim 1, wherein, in the first step, the nitrogen-containing reducing gas is set to have a partial pressure of 15 Pa or less within the process container.

[6] The film formation method according to claim 1, wherein, in film formation, the target substrate is set at a temperature of 400℃ or less.

[7] A film formation method for forming a TiN film having a predetermined thickness on a target substrate by heating the target substrate at a film formation temperature within a process container and performing a cycle comprising a first step and a second step at least once, such that the first step is arranged to supply a Ti compound gas and a nitrogen-containing reducing gas to form a film of TiN by CVD, and the second step is arranged to stop the Ti compound gas and supply the nitrogen-containing reducing gas,

wherein, in film formation, the target substrate is set at a temperature of less than 450℃, the process container is set to have therein a total pressure of more than 100 Pa, and the nitrogen-containing reducing gas is set to have a partial pressure of 30 Pa or less within the process container in the first step.

[8] The film formation method according to claim 7, wherein the Ti compound gas is $TiCl_4$ and the nitrogen-containing reducing gas is NH_3.

[9] The film formation method according to claim 7, wherein a film thickness obtained by the cycle performed once is set to be 0.50 nm or less.

[10] The film formation method according to claim 7, wherein, in the first step, the nitrogen-containing reducing gas is set to have a partial pressure of 20 Pa or less within the process container.

[11] The film formation method according to claim 10, wherein a film thickness obtained by the cycle performed once is set to be 2.0 nm or less.

[12] The film formation method according to claim 7, wherein, in the first step, the nitrogen-containing reducing gas is set to have a partial pressure of 15 Pa or less within the process container.

[13] The film formation method according to claim 7, wherein, in film formation, the target substrate is set at a temperature of 400℃ or less.

[14] The film formation method according to claim 7, wherein, in the first step, the nitrogen-containing reducing gas is set at a flow rate of 20 mL/min or more.

[15] The film formation method according to claim 7, wherein, in the first step, the Ti compound gas is set to have a partial pressure of more than 10 Pa and not more than 50 Pa.

[16] The film formation method according to claim 7, wherein the TiN film is set to have a resistivity of 800 μΩ-cm or less.

[17] A film formation method for forming an initial metal nitride film having a first thickness on a target substrate by heating the target substrate at a film formation temperature within a process container and performing a cycle comprising a first step and a second step at least once, such that the first step is arranged to supply a metal compound gas and a nitrogen-containing reducing gas to form a film of a metal nitride by CVD, and the second step is arranged to stop the metal compound gas and supply the nitrogen-containing reducing gas; and then forming thereon an additional metal nitride film having a second thickness by continuous CVD arranged to supply a metal compound gas and a nitrogen-containing reducing gas onto the target substrate,

wherein, in formation of the initial metal nitride film, the target substrate is set at a temperature of less than 450℃, the process container is set to have therein a total pressure of more than 100 Pa, and the nitrogen-containing reducing gas is set to have a partial pressure of 30 Pa or less within the process container in the first step.

[18] The film formation method according to claim 17, wherein the first thickness is smaller than the second thickness.

[19] The film formation method according to claim 17, wherein formation of the additional metal nitride

film is performed at a film formation temperature of 450℃ or more.

[20] The film formation method according to claim 17, wherein the first thickness is set to be 5 to 50 nm and the second thickness is set to be 5 to 95 nm.

[21] A film formation method for forming an initial metal nitride film having a first thickness on a target substrate by heating the target substrate at a film formation temperature within a process container and performing a cycle comprising a first step and a second step at least once, such that the first step is arranged to supply a metal compound gas and a nitrogen-containing reducing gas to form a film of a metal nitride by CVD, and the second step is arranged to stop the metal compound gas and supply the nitrogen-containing reducing gas; and then forming thereon an additional metal nitride film having a second thickness by performing a cycle comprising the first step and the second step at least once,

wherein, in formation of the initial metal nitride film, the target substrate is set at a temperature of less than 450℃, the process container is set to have therein a total pressure of more than 100 Pa, and the nitrogen-containing reducing gas is set to have a partial pressure of 30 Pa or less within the process container in the first step, and wherein, in formation of the additional metal nitride film, the nitrogen-

containing reducing gas is set to have a partial pressure of more than 30 Pa within the process container in the first step.

[22] The film formation method according to claim 21, wherein formation of the additional metal nitride film is performed at a film formation temperature of 450℃ or more.

[23] The film formation method according to claim 21, wherein the first thickness is set to be 5 to 50 nm and the second thickness is set to be 5 to 95 nm.

[24] A film formation method for forming a metal nitride film having a predetermined thickness on a target substrate by heating the target substrate at a film formation temperature within a process container and performing a cycle comprising a first step and a second step at least once, such that the first step is arranged to supply a metal compound gas and a nitrogen-containing reducing gas to form a film of a metal nitride by CVD, and the second step is arranged to stop the metal compound gas and supply the nitrogen-containing reducing gas,

wherein, in film formation, the target substrate is set at a temperature of less than 450℃, and the process container is set to have therein a total pressure of more than 100 Pa, and wherein the metal nitride film is set to have a resistivity R of 800 $\mu\Omega$-cm or less calculated by a following formula (A);

$$R = 115.75 \times \mathrm{Ln}(T_{hk}) + 71.576 \times \mathrm{Ln}(P_N) + 418.8 \quad \ldots (A)$$

where P_N (Pa) denotes a partial pressure of the nitrogen-containing reducing gas within the process container in the first step, and T_{hk} (nm) denotes a film thickness obtained by the cycle performed once.

[25] The film formation method according to claim 24, wherein the metal compound gas is a Ti compound gas and the metal nitride film is a TiN film.

[26] The film formation method according to claim 25, wherein the Ti compound gas is $TiCl_4$ and the nitrogen-containing reducing gas is NH_3.

[27] A film formation method for forming a metal nitride film having a predetermined thickness on a target substrate by heating the target substrate at a film formation temperature within a process container and performing a cycle comprising a first step and a second step at least once, such that the first step is arranged to supply a metal compound gas and a nitrogen-containing reducing gas to form a film of a metal nitride by CVD, and the second step is arranged to stop the metal compound gas and supply the nitrogen-containing reducing gas,

wherein, in film formation, the target substrate is set at a temperature of less than 450℃, and the process container is set to have therein a total pressure of more than 100 Pa, and wherein the metal nitride film is set to have a resistivity R of 800 μΩ-

cm or less calculated by a following formula (B);

$$R = 115.75 \times \mathrm{Ln}(T_{hk}) + 71.576 \times \mathrm{Ln}(P_N) - 57.685 \times \mathrm{Ln}(F_N) + 614 \quad \ldots (B)$$

where P_N (Pa) denotes a partial pressure of the nitrogen-containing reducing gas within the process container in the first step, T_{hk} (nm) denotes a film formation thickness obtained by the cycle performed once, and F_N (mL/min) denotes a flow rate of the nitrogen-containing reducing gas in the first step.

[28] The film formation method according to claim 27, wherein the metal compound gas is a Ti compound gas and the metal nitride film is a TiN film.

[29] The film formation method according to claim 28, wherein the Ti compound gas is $TiCl_4$ and the nitrogen-containing reducing gas is NH_3.

[30] A film formation method for forming a metal nitride film having a predetermined thickness on a target substrate by heating the target substrate at a film formation temperature within a process container and performing a cycle comprising a first step and a second step at least once, such that the first step is arranged to supply a metal compound gas and a nitrogen-containing reducing gas to form a film of a metal nitride by CVD, and the second step is arranged to stop the metal compound gas and supply the nitrogen-containing reducing gas,

wherein, in film formation, the target substrate

is set at a temperature of less than 450℃, and the process container is set to have therein a total pressure of more than 100 Pa, and wherein the metal nitride film is set to have a resistivity R of 800 $\mu\Omega$-cm or less calculated by a following formula (C);

$$R = 115.75\times Ln(T_{hk}) + 71.576\times Ln(P_N) - 57.685\times Ln(F_N) - 2844.6Ln(T_W) + 17658.3 \quad ...(C)$$

where P_N (Pa) denotes a partial pressure of the nitrogen-containing reducing gas within the process container in the first step, T_{hk} (nm) denotes a film formation thickness obtained by the cycle performed once, F_N (mL/min) denotes a flow rate of the nitrogen-containing reducing gas in the first step, and T_W (℃) denotes temperature of the target substrate.

[31] The film formation method according to claim 30, wherein the metal compound gas is a Ti compound gas and the metal nitride film is a TiN film.

[32] The film formation method according to claim 31, wherein the Ti compound gas is $TiCl_4$ and the nitrogen-containing reducing gas is NH_3.

[33] A computer readable medium containing software for a computer to control a film formation apparatus, so as to form a metal nitride film having a predetermined thickness on a target substrate by heating the target substrate at a film formation temperature within a process container and performing a cycle comprising a first step and a second step at

least once, such that the first step is arranged to supply a metal compound gas and a nitrogen-containing reducing gas to form a film of a metal nitride by CVD, and the second step is arranged to stop the metal compound gas and supply the nitrogen-containing reducing gas, wherein, in film formation, the target substrate is set at a temperature of less than 450℃, the process container is set to have therein a total pressure of more than 100 Pa, and the nitrogen-containing reducing gas is set to have a partial pressure of 30 Pa or less within the process container in the first step.

[34] A computer readable medium containing software for a computer to control a film formation apparatus, so as to form a TiN film having a predetermined thickness on a target substrate by heating the target substrate at a film formation temperature within a process container and performing a cycle comprising a first step and a second step at least once, such that the first step is arranged to supply a Ti compound gas and a nitrogen-containing reducing gas to form a film of TiN by CVD, and the second step is arranged to stop the Ti compound gas and supply the nitrogen-containing reducing gas, wherein, in film formation, the target substrate is set at a temperature of less than 450℃, the process container is set to have therein a total pressure of more than 100

Pa, and the nitrogen-containing reducing gas is set to have a partial pressure of 30 Pa or less within the process container in the first step.

[35] A computer readable medium containing software for a computer to control a film formation apparatus, so as to form a metal nitride film having a predetermined thickness on a target substrate by heating the target substrate at a film formation temperature within a process container and performing a cycle comprising a first step and a second step at least once, such that the first step is arranged to supply a metal compound gas and a nitrogen-containing reducing gas to form a film of a metal nitride by CVD, and the second step is arranged to stop the metal compound gas and supply the nitrogen-containing reducing gas, wherein, in film formation, the target substrate is set at a temperature of less than 450℃, and the process container is set to have therein a total pressure of more than 100 Pa, and wherein the metal nitride film is set to have a resistivity R of 800 $\mu\Omega$-cm or less calculated by a following formula (A);

$$R = 115.75 \times \mathrm{Ln}(T_{hk}) + 71.576 \times \mathrm{Ln}(P_N) + 418.8 \quad \ldots (A)$$

where P_N (Pa) denotes a partial pressure of the nitrogen-containing reducing gas within the process container in the first step, and T_{hk} (nm) denotes a film thickness obtained by the cycle performed once.

[36] The medium according to claim 35, wherein the metal compound gas is a Ti compound gas and the metal nitride film is a TiN film.

[37] A computer readable medium containing software for a computer to control a film formation apparatus, so as to form a metal nitride film having a predetermined thickness on a target substrate by heating the target substrate at a film formation temperature within a process container and performing a cycle comprising a first step and a second step at least once, such that the first step is arranged to supply a metal compound gas and a nitrogen-containing reducing gas to form a film of a metal nitride by CVD, and the second step is arranged to stop the metal compound gas and supply the nitrogen-containing reducing gas, wherein, in film formation, the target substrate is set at a temperature of less than 450℃, and the process container is set to have therein a total pressure of more than 100 Pa, and wherein the metal nitride film is set to have a resistivity R of 800 $\mu\Omega$-cm or less calculated by a following formula (B);

$$R = 115.75 \times Ln(T_{hk}) + 71.576 \times Ln(P_N) - 57.685 \times Ln(F_N) + 614 \quad ...(B)$$

where P_N (Pa) denotes a partial pressure of the nitrogen-containing reducing gas within the process container in the first step, T_{hk} (nm) denotes a film

formation thickness obtained by the cycle performed once, and F_N (mL/min) denotes a flow rate of the nitrogen-containing reducing gas in the first step.

[38] The medium according to claim 37, wherein the metal compound gas is a Ti compound gas and the metal nitride film is a TiN film.

[39] A computer readable medium containing software for a computer to control a film formation apparatus, so as to form a metal nitride film having a predetermined thickness on a target substrate by heating the target substrate at a film formation temperature within a process container and performing a cycle comprising a first step and a second step at least once, such that the first step is arranged to supply a metal compound gas and a nitrogen-containing reducing gas to form a film of a metal nitride by CVD, and the second step is arranged to stop the metal compound gas and supply the nitrogen-containing reducing gas, wherein, in film formation, the target substrate is set at a temperature of less than 450℃, and the process container is set to have therein a total pressure of more than 100 Pa, and wherein the metal nitride film is set to have a resistivity R of 800 $\mu\Omega$-cm or less calculated by a following formula (C);

$$R = 115.75\times\mathrm{Ln}(T_{hk}) + 71.576\times\mathrm{Ln}(P_N) - 57.685\times\mathrm{Ln}(F_N) - 2844.6\mathrm{Ln}(T_W) + 17658.3 \quad \ldots(C)$$

where P_N (Pa) denotes a partial pressure of the nitrogen-containing reducing gas within the process container in the first step, T_{hk} (nm) denotes a film formation thickness obtained by the cycle performed once, F_N (mL/min) denotes a flow rate of the nitrogen-containing reducing gas in the first step, and T_W (℃) denotes temperature of the target substrate.

[40] The medium according to claim 39, wherein the metal compound gas is a Ti compound gas and the metal nitride film is a TiN film.